CHAPTER 5: APPLICATION TO DEVELOPMENT OF A FLORIDA BAY MFL

SUMMARY OF TECHNICAL RELATIONSHIPS ANALYSES

Summary of Hydrologic Analyses

As part of the process to determine relationships between the amount of managed freshwater inflow and impacts to resources in Florida Bay, two models were used to predict salinities at various locations in Florida Bay:

- An updated FATHOM model was used to estimate salinity for each of 41 basins within Florida Bay for the historical period from 1970 to 2002.
- An existing multivariate linear regression (MLR) model was used to develop a time series of salinity conditions at the Taylor River station for this same time period.

FATHOM Model

The FATHOM model (Flux-Accounting Tidal Hydrology Ocean Model) was refined by including an updated bathymetry dataset, inflows, hydrologic data and time-varying salinity boundary conditions along the western boundary with the Gulf of Mexico (ECT, Inc. 2005). The result was considered a reconstruction that represents an approximation of the historical water budget. The model was calibrated with data collected during the 1991–2002 period. Model fidelity and predictions for this period varied somewhat by basin, but overall the FATHOM model explained about 81 percent of the observed monthly salinity variability throughout the 41 basins. Along the representative gradient, the FATHOM model explained 76 percent of the monthly salinity variability in Little Madeira Basin and 77 percent in Eagle Key Basin, sites located along the Everglades-Florida Bay Transition Zone transect.

The ability of the model to predict salinity under managed flow conditions was also assessed. Annual maximum salinities in basins located in the northeast and eastern interior region of Florida Bay were significantly correlated to year-to-year changes in inflow. The total average annual inflow to northeast Florida Bay shows an increasing trend over the 31-year period 1970 to 2000, but water budgets and flows into northeast Florida Bay prior to 1980 were distinctly different from those after 1980. The relative amount of surface water discharged into the Everglades–Florida Bay transition zone for a given rainfall amount after 1981 was about four times higher than the amount discharged during the period from 1970 to 1981. The difference is attributed primarily to changes in water management activities.

Two representative drought years, near the 10 percent probability level, occurred during the 31-year simulation period: 1971 and 1990. To account for apparent changes in water management practices, normal and dry years were defined in both the pre-1980 and post-1980 periods. This analysis indicated that even though the 1975 water year (Nov. 1, 1974 – Oct 31, 1975) had precipitation near the long-term average, the annual inflow to the Everglades–Florida Bay transition zone was comparable to the 1989–1990 drought period, due to water management practices.

Multivariate Linear Regression (MLR) Model

The second (MLR) model was applied to the Taylor River station, located at the upstream area of Everglades–Florida Bay transition zone for the historical period from 1970 to 2002. This model uses observed water level data from key gauges within Everglades National Park to predict salinity at the Taylor River monitoring site. The MLR model was used for this area because the FATHOM model does not extend to the upper reaches of Taylor River. The model was calibrated against field measurements collected during the 1988–2000 period and was shown to provide reasonable salinity estimates. The efficiency of the MLR model (a measure of the percentage of variance explained by the model variability) for monthly estimates was 84 percent. The largest errors tend to occur at the onset of the wet season and during extended periods of low flow.

Summary of Ecological Analyses

Submerged aquatic vegetation (SAV) habitat of the Everglades–Florida Bay transition zone along the coastline is sensitive to salinity, with loss of all major species occurring at levels above 30 psu. *Ruppia maritima*, the dominant vascular SAV of the transition zone, is the most salinity tolerant of this assemblage. The loss of this species near 30 psu is related not only to mortality of seedlings and of adult plants but also to inhibition of seed germination and of reproductive success above this salinity level. *Ruppia maritima* is proposed as an indicator species for the status of the transition zone-Florida Bay ecosystem.

SAV habitat in open water areas of northeastern Florida Bay is dominated by two species: *Halodule wrightii* and *Thalassia testudinum*. These species are more salinity tolerant than *Ruppia* and under optimal laboratory conditions can tolerate extremely high salinity levels (near 60 psu). Empirical field data do not show clear salinity trends, but these data are limited to low and moderate salinity conditions and insufficient to assess effects of hypersalinity. A dynamic simulation model of *Halodule* and *Thalassia* indicates that strong effects of salinity are likely to occur in the field because field conditions are not optimal. In particular, the effects of salinity are probably the indirect result of effects on competition between *Thalassia* and *Halodule* (especially for nutrients and light). Results based on field data and modeling suggest that under hypersaline conditions (above 40 psu), *Thalassia* becomes dominant, while under mesohaline conditions (less than 18 psu), *Halodule* is predicted to become dominant.

The quantitative and qualitative composition of the SAV community appears to have an impact on many fish and invertebrate species of Florida Bay. A statistical analysis of a multidecadal dataset from Florida Bay demonstrated that salinity has a significant (though widely varying) effect on these fauna and also that almost all fauna benefit from increased *Halodule* cover. Analyses indicate that in Florida Bay increasing the salinity level from mesohaline toward marine and hypersaline conditions tends to reduce the overall abundance of the forage base (small animals that are food for larger fish, particularly for sport fish) because of direct salinity effects on these organisms and because of loss of SAV habitat. Maintaining an estuarine condition (salinity commonly less than marine levels) will thus be protective of both habitat and faunal resources.

IDENTIFICATION OF FRESHWATER INFLOW-RESOURCE IMPACT RELATIONSHIPS

Key Findings

Based on analyses of hydrologic-ecologic relationships and results presented in Chapter 4, the following are key findings relevant to the development of the Florida Bay MFL.

- By analyzing salinity and resources along the Everglades-Florida Bay Transition Zone transect, conditions and impacts in Taylor River, downstream coastal embayments and northeastern Florida Bay can be examined concurrently.
- Freshwater discharges from the regional water management system have direct effects on salinity conditions and the ecology of the transition zone, coastal embayments of northeastern Florida Bay, and northeastern Florida Bay proper.
- The availability of submerged aquatic vegetation (SAV) habitat within the Taylor River gradient is an indicator of the health of the entire transition zone and of the adjacent northeastern Florida Bay ecosystem.
- Resources and functions of the transition zone and northeastern Florida Bay can be protected from negative impacts by taking appropriate actions to prevent multi-year recurrences of high salinity levels that jeopardize SAV habitat in the transition zone. For the Taylor River site, significant adverse changes occur in the SAV community when monthly average salinities exceed 30 psu.
- Field and laboratory studies indicate that when monthly average salinity exceeds 30 psu at the Taylor River site there is a loss of *Ruppia maritima* cover and the SAV community in this region. Recovery to pre-existing conditions would be expected to take a year or more.
- Re-occurrence of such conditions (monthly average salinity exceeding 30 psu) at the Taylor River site during successive years prevents the successful recovery of *Ruppia maritima* cover and the SAV community in this region and results in a sustained multi-year impacts to the resource. Greater duration and frequency of these adverse salinity conditions tend to exert correspondingly greater negative impact on the survival of the SAV community and associated organisms, as well as on productivity and water quality in the Everglades–Florida Bay transition zone, while allowing insufficient time for recovery to occur.
- Such salinity conditions also affect adjacent downstream basins in northeastern Florida Bay. During periods when monthly average salinities in the transition zone are above 30 psu, salinities in northeastern Florida Bay generally exceed 40 psu and may be considerably higher. Field and modeling studies indicate that extended periods of salinity above 40 psu in this region result in decreased *Halodule wrightii* (shoal grass) cover and adverse effects on upper-trophic-level organisms that utilize this habitat.
- Decreases in SAV diversity would be expected to occur under conditions of sustained hypersalinity, and decreases in Florida Bay fauna would be a likely consequence.
- Maintenance of monthly average salinity concentrations below 30 psu at the Taylor River Site should prevent major impacts from occurring to *Ruppia* and associated SAV species in the transition zone and should concurrently sustain conditions in coastal embayments and northeastern Florida Bay to prevent the sustained degradation and loss of SAV habitat and other associated living resources. Corresponding salinity conditions in these downstream estuarine areas are mesohaline (5–18 psu) conditions in the wet season and polyhaline-euhaline (18–40 psu) conditions in the dry season.

Historic Occurrences of Resource Impacts

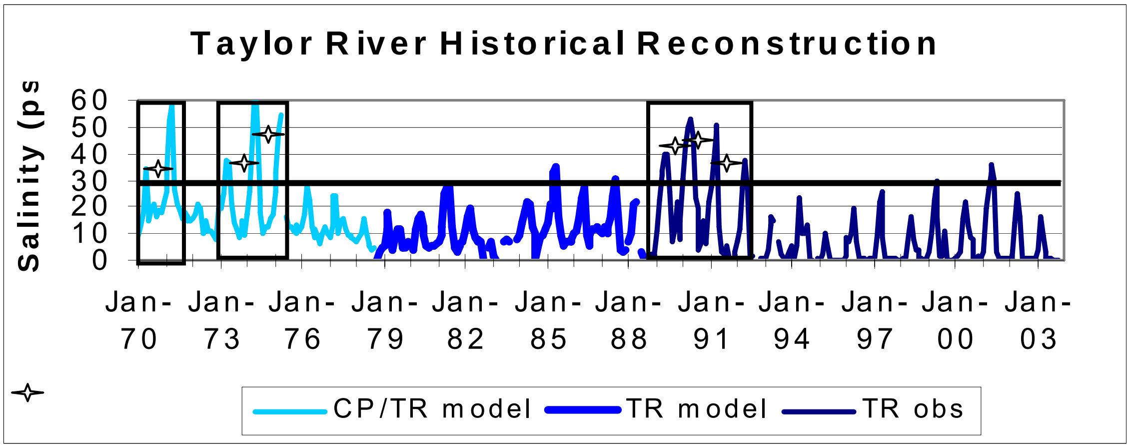
The present chapter examines the link between inflow and salinity during a reconstructed historical period from 1970–2002, and it provides a comparison of 1) the Taylor River estimates from the MLR model and 2) Florida Bay (FATHOM) estimates from the FATHOM model, highlighting the periods in which resource impacts as defined in the preceding section have occurred.

Transition Zone Modeling Results

Historic salinity conditions were reconstructed in the upper transition zone for the period, 1970-2002, using a combination of field measurements, which have been continuous at Taylor River site since October 1988, and estimates from the Taylor River MLR salinity model for 1970–1988 (**Figure 52**). The Taylor River site exhibits variable salinity and becomes hypersaline during the drought years that were identified in the water budget (see **Figure 52** [below] and **Figure 27** in Chapter 4). Analysis of the 33-year historical reconstruction of salinity for the Taylor River site indicated that the salinity threshold that impacts to SAV resources (monthly average salinity above 30 ppt) was exceeded during the 1970-2002 period as follows:

- Monthly average salinities exceeded 30 ppt during 12 of the 31 years
- Monthly average salinities exceeded 30 ppt during two successive years during 1970-71
- Monthly average salinities exceeded 30 ppt for three-years in succession from 1971-1975
- Monthly average salinities exceeded 30 ppt during four successive years from 1989-1992.

The analysis indicates that rainfall conditions were somewhat lower than average during the 1970's and somewhat higher than average during the 1990's. Major regional droughts occurred during the periods from 1971-72, 1974-75 and 1989-92, although 1974 and 1975 were not especially dry years in the southern Everglades and Florida Bay. There have been significant changes in water delivery facilities and practices during this reconstruction period. Current water management facilities and practices had been in place throughout the reconstructed period, some of these periods of high salinity could have been reduced in duration or avoided.



TAYLOR RIVER SITE

YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	TOTAL BAY ANNUAL INFLOW (THOUSANDS ACRE-FEET/ YE
	MEAN MONTHLY SALINITY (psu) FROM HISTORICAL RECONSTRUCTION USING MIXED MLR ANALYSES												
1970	0	9	13	18	34	20	14	19	21	17	18	18	**50**
1971	22	26	34	52	58	27	21	19	16	18	16	15	**20**
1972	15	15	17	21	20	10	10	15	11	11	9	8	162
1973	19	23	20	25	38	37	21	14	11	9	12	15	**84**
1974	9	17	26	46	68	49	22	18	10	13	13	15	**39**
1975	17	26	33	48	54	0	17	12	12	11	10	13	**71**
1976	11	13	17	28	22	13	9	12	10	7	10	12	139
1977	10	8	13	24	25	10	15	15	12	9	9	8	118
1978	8	7	8	10	15	10	6	5	4	5	0	3	127
1979	5	5	12	18	8	4	9	12	11	5	5	0	80
1980	7	6	4	12	16	17	12	10	6	5	5	5	115
1981	6	7	9	12	25	27	28	13	5	3	6	6	185
1982	7	11	17	19	12	9	7	8	7	1	0	4	168
1983	7	1	0	0	0	0	7	8	7	0	5	0	292
1984	8	10	14	18	22	21	13	10	0	5	8	9	178
1985	12	14	21	19	32	35	16	9	5	7	7	7	232
1986	8	10	11	16	23	27	10	6	9	12	12	13	205
1987	11	10	12	10	12	15	24	30	17	4	4	4	210
1988	0	7	10	21	22	0	3	1	0	0	1	3	278
1989	2	11	23	32	34	40	40	26	7	11	22	8	**83**
1990	15	31	43	50	53	47	24	19	4	6	15	6	**103**
1991	22	28	38	49	51	13	3	2	5	1	1	1	189
1992	3	7	12	27	37	27	1	1	0	1	0	1	222
1993	1	1	4	13	17	15	0	7	2	0	0	3	287
1994	5	1	1	5	23	10	10	13	1	0	0	0	394
1995	1	0	2	9	10	5	0	0	0	0	0	0	374
1996	2	8	7	10	19	7	0	1	0	0	0	0	214
1997	1	1	9	22	26	9	1	1	1	0	1	0	312
1998	0	0	1	1	9	16	8	4	4	0	1	0	281
1999	0	3	10	22	30	16	1	1	11	0	0	0	303
2000	0	0	1	3	15	22	13	8	8	0	0	1	323
2001	1	3	20	26	32	36	31	3	1	0	0	1	312
2002	1	1	1	14	25	16	1	1	0	1	1	1	256

KEY	SALINITY (PSU)	
	50+	HYPERSALINE++
	40 - 49	HYPERSALINE
	30 - 39	EUHALINE
	19 - 29	POLYHALINE
	6 -18	MESOHALINE
	0 - 5	OLIGOHALINE

Figure 52. Historical Reconstruction for Salinity Time Series at the Taylor River Site. Data from Marshall 2005. Top: time series of monthly estimates using a multiple linear regression model for station TR from 1970-1988 (using estimated stage values at station CP from 1970-1978) and observed data from TR after October 1988. Six periods of two consecutive years when monthly average salinity exceeded 30 psu are identified during the periods shown in the boxes (1970–1971, 1973–1975 and 1989–1992). Bottom: table format of same salinity time series at TR with color coding of salinity intervals and associated annual fresh water flow to northeastern Florida Bay.

The analysis also suggests that, in addition to monitoring flow into northeastern Florida Bay and salinity at the Taylor River site, the likelihood that monthly average salinities will exceed 30 psu can be anticipated or monitored by observing the stage of fresh water in the southern Everglades. Daily stage values at Craighead Pond (CP) fall below -1 feet NGVD29 during the years when monthly average salinities at Taylor River exceed 30 psu and may be used as a local indicator that inflow is critically low. A lowered water level gradient (<3') between stations P33 and P35 corresponds to regional drought periods during the historical reconstruction period (**Figure 53**).

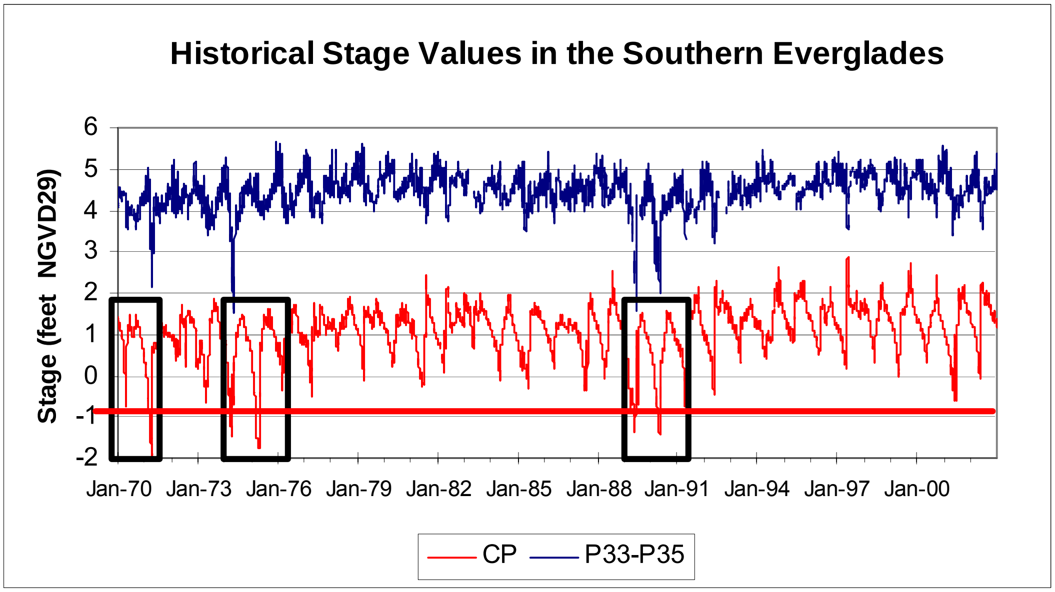


Figure 53. Daily Stage Values in the Southern Everglades over the Historical Reconstruction Period. The stages shown (from Marshall 2005) are used in the TR salinity model; data are based on observation except at Craighead Pond [CP] from the period 1970–1978, during which observation data are not available; estimates during this period were made based on a regression model (Marshall 2005). Daily stage values at CP that fall below -1 ft [NGVD29] during consecutive years also correspond to the time periods when salinities at Taylor River exceeded 30 psu; the gradient between P33 and P35 (within Shark River Slough) falls below 3 ft NGVD29 during regional drought periods, although low water levels at CP can occur more frequently.

Northeastern Florida Bay Modeling Results

The variation of monthly salinity between the lower portion of the Everglades-Florida Bay Transition Zone transect (inner Little Madeira Bay/mouth of Taylor River) to outer Little Madeira Bayand Eagle Key) reflects the influence of climatic variability and water management. Monthly mean salinity varied greatly (from 7 to 57 psu) over the 33-year historical reconstruction period at three estuarine sites (inner Little Madeira Bay, outer Little Madeira Bay, Eagle Key Basin). Conditions range from consistently hypersaline and euhaline in years of low flow and/or drought to dominantly polyhaline and mesohaline in years of normal and higher rainfall. Oligohaline conditions are not typical along this lower portion of the gradient and are restricted to the transition zone. The timing of hypersalinity in the estuary corresponded with high salinity in the transition zone. Persistent hypersaline periods existed in estuarine waters along the transect during periods of low fresh water flow when monthly average salinity exceeded 30 psu at the Taylor River site during consecutive years (see **Figure 54**; **Figure 25** and **Figure 26** in Chapter 4).

a.

INNER LITTLE MADEIRA BAY

MEAN MONTHLY SALINITY(psu) AS PREDICTED BY FATHOM MODEL

YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	TOTAL BAY ANNUAL (THOUSANDS ACRE-
1970	50	48	47	51	51	44	37	39	40	38	39	42	**50**
1971	44	46	49	53	57	54	52	52	49	45	44	43	**20**
1972	43	44	45	45	39	22	14	19	24	26	28	30	162
1973	32	33	34	38	41	38	34	27	23	26	29	31	**84**
1974	32	35	38	41	42	40	37	36	38	40	42	44	**39**
1975	45	47	49	52	50	42	36	34	33	33	35	37	**71**
1976	38	39	41	44	41	28	23	22	18	22	27	30	139
1977	32	33	36	40	36	30	31	36	28	24	28	30	118
1978	31	31	32	34	34	32	32	31	25	21	23	27	127
1979	31	33	37	33	29	31	34	35	33	31	33	34	80
1980	35	37	39	41	42	35	28	27	27	28	29	28	115
1981	30	30	31	35	40	42	43	26	12	12	18	22	185
1982	26	29	30	27	25	19	17	19	19	18	17	19	168
1983	18	12	9	9	12	13	14	14	11	14	16	17	292
1984	22	25	28	31	31	27	22	18	16	18	23	27	178
1985	30	32	34	36	38	37	26	20	18	15	17	19	232
1986	21	24	25	26	32	31	24	19	21	28	33	32	205
1987	30	32	33	35	36	36	38	37	29	20	16	17	210
1988	20	23	29	35	35	22	10	7	8	12	16	21	278
1989	24	28	32	35	41	44	40	33	31	33	38	40	**83**
1990	43	47	49	50	49	46	47	42	35	35	37	41	**103**
1991	44	46	48	51	46	37	35	33	26	22	24	28	189
1992	31	33	35	37	40	29	19	19	17	20	20	21	222
1993	19	18	20	22	24	21	19	18	16	14	15	20	287
1994	22	19	18	20	22	22	24	23	14	12	13	12	394
1995	10	9	12	15	16	13	10	10	10	12	13	15	374
1996	16	17	19	22	22	16	13	13	13	10	12	17	214
1997	18	20	23	27	29	19	12	12	10	11	16	14	312
1998	12	12	9	10	14	19	23	23	17	14	14	15	281
1999	18	21	24	28	32	28	23	20	16	11	11	13	303
2000	12	12	14	18	23	23	20	16	13	12	15	18	323
2001	20	23	27	29	31	31	26	17	11	9	10	12	312
2002	13	15	19	24	26	18	10	10	12	16	21	23	256

b.

OUTER LITTLE MADEIRA BAY

MEAN MONTHLY SALINITY(psu) AS PREDICTED BY FATHOM MODEL

YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	TOTAL BAY ANNUAL (THOUSANDS ACRE
1970	48	47	47	49	49	45	40	40	40	39	39	41	**50**
1971	43	45	46	50	53	52	51	51	49	45	43	43	**20**
1972	42	43	44	45	41	30	24	26	28	29	30	31	162
1973	33	33	35	37	40	38	36	32	28	29	31	32	**84**
1974	33	35	37	40	41	40	39	39	40	41	42	43	**39**
1975	44	45	47	49	49	44	40	38	36	35	36	37	**71**
1976	38	38	40	42	41	33	30	29	26	27	30	32	139
1977	33	33	36	39	37	34	35	38	33	30	31	32	118
1978	33	32	33	35	35	34	34	34	30	27	27	30	127
1979	32	34	36	35	33	35	36	37	35	33	34	35	80
1980	36	37	39	40	41	38	33	33	32	32	32	31	115
1981	32	32	33	36	39	41	42	32	22	20	22	25	185
1982	27	29	31	29	27	23	21	23	23	23	22	23	168
1983	22	17	15	14	16	18	19	19	18	19	20	21	292
1984	24	27	29	31	32	31	28	26	24	24	27	30	178
1985	32	33	35	36	38	38	31	28	26	24	24	25	232
1986	26	27	28	30	33	34	31	29	30	33	36	35	205
1987	33	34	35	36	37	37	39	40	35	29	25	25	210
1988	26	28	31	35	36	28	20	16	16	18	21	24	278
1989	27	30	32	35	40	43	41	38	37	38	40	42	**83**
1990	43	46	48	49	48	47	48	45	41	40	41	43	**103**
1991	45	46	47	49	47	42	40	38	33	29	29	31	189
1992	33	34	36	37	40	33	26	26	25	26	25	25	222
1993	24	22	24	25	27	26	25	25	23	21	21	25	287
1994	26	24	23	25	27	27	29	29	23	20	19	18	394
1995	17	16	18	19	20	18	16	16	16	16	16	18	374
1996	19	20	22	24	25	21	19	19	19	17	17	20	214
1997	21	22	25	28	30	24	20	19	17	17	20	19	312
1998	18	17	15	15	19	23	27	28	24	21	20	21	281
1999	22	24	26	29	33	31	28	26	23	18	17	17	303
2000	17	17	19	22	25	26	24	22	20	20	20	22	323
2001	23	25	28	30	32	32	30	25	20	17	17	18	312
2002	18	19	22	26	28	23	17	17	18	21	24	26	256

c.

EAGLE KEY- NE INTERIOR REGION

MEAN MONTHLY SALINITY(psu) AS PREDICTED BY FATHOM MODEL

YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL BAY ANNUAL INFLOW (THOUSANDS ACRE-FEET /YEAR)
1970	46	46	46	48	48	45	44	42	41	40	40	41	**50**
1971	42	43	44	46	49	50	50	50	48	46	43	42	**20**
1972	42	42	43	44	43	39	34	34	33	32	32	33	162
1973	34	34	35	37	39	39	38	36	34	32	32	33	**84**
1974	33	35	37	39	41	41	41	41	41	42	42	43	**39**
1975	43	44	45	47	47	45	43	41	39	38	38	38	**71**
1976	38	38	39	41	41	38	36	35	33	32	33	34	139
1977	34	34	36	38	39	38	39	40	39	36	35	34	118
1978	34	34	34	36	36	35	36	36	35	33	32	33	127
1979	33	34	36	37	37	38	38	38	38	36	36	37	80
1980	37	37	38	39	40	40	39	38	37	36	35	34	115
1981	34	35	35	36	39	40	41	38	31	27	27	27	185
1982	29	30	31	30	29	27	25	26	27	28	27	27	168
1983	26	23	21	20	21	23	23	25	25	24	25	25	292
1984	27	29	30	32	34	34	34	34	32	31	31	32	178
1985	33	34	35	37	38	38	37	37	35	33	31	31	232
1986	30	31	31	33	35	37	39	39	38	39	39	38	205
1987	36	36	36	37	38	39	41	43	42	38	34	32	210
1988	32	32	34	36	37	34	29	25	23	24	25	27	278
1989	29	31	33	36	39	42	43	43	42	42	42	43	**83**
1990	44	46	47	48	48	48	49	49	47	45	45	45	**103**
1991	45	46	47	48	48	46	45	43	40	36	33	34	189
1992	34	35	37	38	40	37	34	33	32	31	30	30	222
1993	29	27	28	29	30	30	31	31	30	28	28	29	287
1994	30	29	29	31	32	33	34	35	32	28	26	25	394
1995	23	23	24	24	25	24	23	22	21	20	20	21	374
1996	22	23	24	26	27	26	25	25	25	23	22	23	214
1997	24	25	26	29	31	30	28	27	25	23	24	24	312
1998	23	23	21	21	23	26	30	32	30	28	27	26	281
1999	27	27	28	31	33	33	32	32	29	25	22	22	303
2000	23	23	24	26	28	29	29	29	28	27	26	26	323
2001	26	28	29	31	33	34	34	32	29	25	23	23	312
2002	24	24	25	28	30	28	25	24	25	26	28	28	256

KEY	SALINITY (PSU)	
	50+	HYPERSALINE++
	40 - 49	HYPERSALINE
	30 - 39	EUHALINE
	19 - 29	POLYHALINE
	6 - 18	MESOHALINE
	0 - 5	OLIGOHALINE

Figure 54. Monthly Salinity Conditions within the Florida Bay portion of the Everglades-Florida Bay gradient. Output from the FATHOM model (ECT 2005) was used to develop salinity-flow illustrations for the reconstructed historical conditions at three locations along the Taylor River–Little Madeira gradient within Florida Bay (see **Figure 23**). The outer Little Madeira values (panel b) were obtained by averaging data from panels a and c; the years within the boxes correspond to the periods when monthly average salinity at the Taylor River site exceeded 30 psu during consecutive years; when low flow conditions (< 105 acre-feet /year) occur for two or more consecutive years, then hypersaline conditions (> 40 psu) persist for during the next year's dry season).

During those periods, salinity conditions downstream in Little Madeira Bay, Eagle Key Basin and northeastern Florida Bay were considerably higher and persisted longer than at the Taylor River Site. Results indicated that whereas salinity at the Taylor River site during low-flow periods exceeded 30 psu for 2-5 months, salinity in Little Madeira Bay and Eagle Key Basin remained above 30 psu for a year or more and were above 40 psu for several months. Periods of prolonged marine to hypersaline conditions can result in a loss of estuarine function within Florida Bay, including the loss of *Halodule wrightii* and negative impacts on fish and other fauna downstream in Little Madeira Bay and Eagle Key Basin (see Chapter 4).

FATHOM results also indicate that hypersaline conditions occur during these same periods in other northeastern and central coastal basins such as Long Sound, Joe Bay and Trout Cove (ECT 2005). Thus, during years when monthly average salinity at the Taylor River site exceeded 30 psu for consecutive years, a substantial part of Florida Bay, including regions that receive direct inflow and that normally have estuarine salinity, experienced hypersaline conditions. The euhaline and hypersaline conditions associated with calendar years of low inflow (**Figure 54)** often persist into a substantial portion of the following calendar year's dry season, and estuarine conditions may not return until the summer or fall of the following year when inflow increases. This timing effectively increases the period of elevated salinity experienced in Florida Bay and indicates that timing of inflow is an important consideration.

Transport time is a widely-used metric in biological and hydrologic studies and can be analyzed using the FATHOM model to estimate the time needed for water to move throughout the system. Turnover time, which is the rate at which an estuary "flushes," or exchanges its water and/or materials such as nutrients, can partially determine the estuary's trophic state and health. The turnover times may be used to compare water exchange differences among Florida Bay's many sub-basins. Turnover time is calculated by FATHOM on a monthly basis for each of the 41 basins and is defined as the monthly average volume of water in a basin divided by the monthly total influx of water into the basin (including flood tides, rainfall and runoff); results are expressed in days (ECT, Inc. 2005). Turnover time (**T_T)** is mathematically equivalent to the classically defined hydraulic retention time of a basin defined as

$$T_T = V/Q$$

where **V** is the volume of the basin and **Q** is the water flux.

Turnover times for the FATHOM basins of Florida Bay range from a few days up to almost six months (ECT, Inc. 2005). Inspection of turnover times and salinity in Florida Bay indicates that periods of rapid increase in salinity coincide with periods of slow turnover (high turnover times) (ECT, Inc. 2005). Basins with slow turnover are more susceptible to development of hypersaline conditions during periods when evaporation is greater than rainfall. FATHOM estimates indicate that in Florida Bay, such basins are found primarily in the eastern region (**Figure 55**). Eastern basins (Long Sound, Joe Bay, Little Madeira Bay, Park Key and Duck Key shown) also have turnover times that are more seasonally variable than those of other bay areas.

Over the historical reconstruction period, the minimum value for turnover times in Little Madeira Bay is 18 days, the median value is 39 days, and the maximum is 82 days. The values for Eagle Key basin (shown as Park Key) are 31 minimum, 58 median and 129 maximum. The previously identified low flow years (1970–1971, 1973–1975 and 1989–1990) exhibit relatively slow turnover times in the dry season in the coastal embayments Little Madeira, Joe Bay and Long Sound. In those years, these embayments experience reduced "flushing," with the attendant increases in salinity and likely increases in retention of nutrients and other materials.

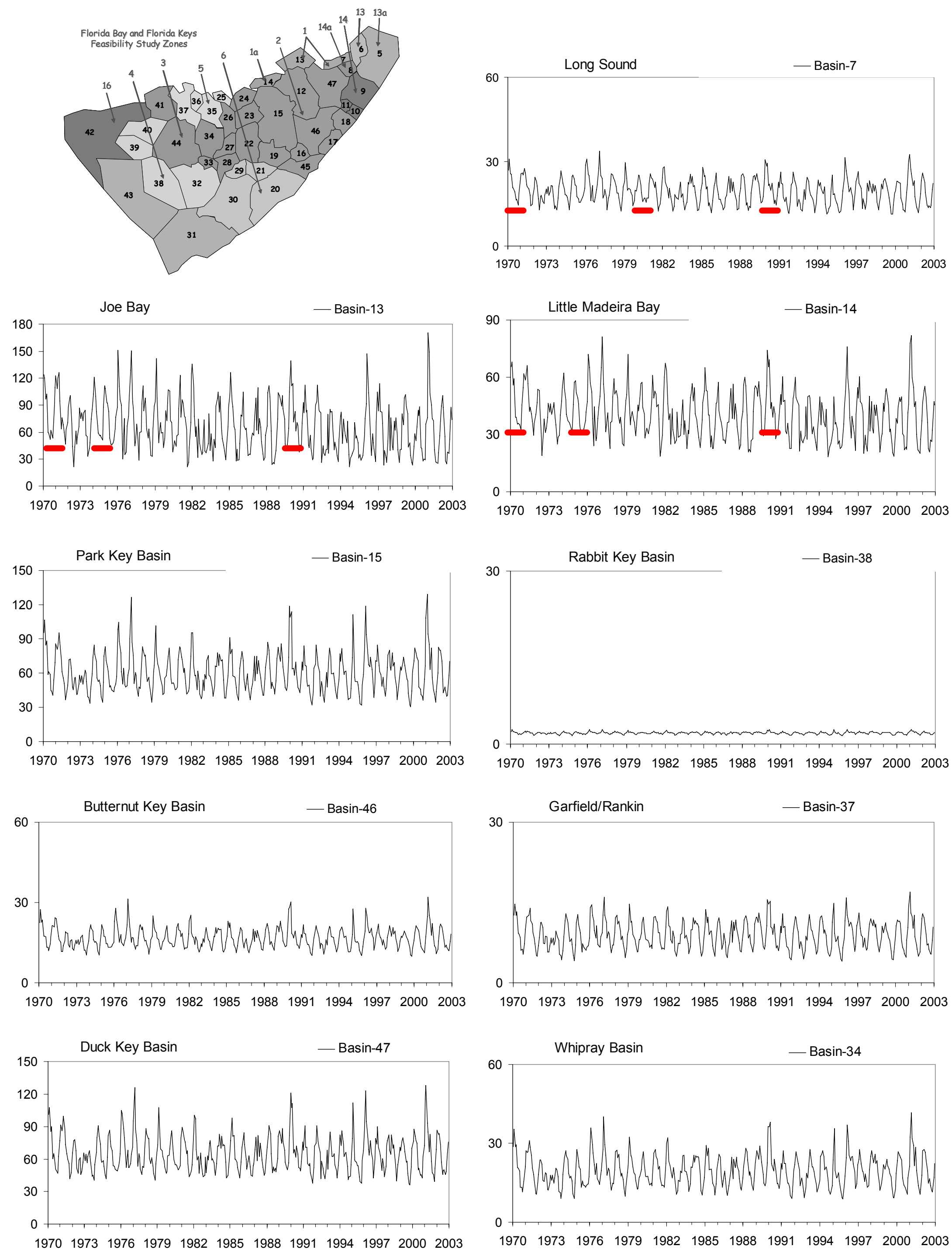


Figure 55. Time Series of Monthly Values of Simulated Turnover Times (Days) for Nine Selected FATHOM Basins (the map on the upper left shows the location of the FATHOM basins; the eastern basin [Long Sound, Joe Bay, Little Madeira Bay, Park Key and Duck Key] shows the most variable turnover rates; the red lines are placed to highlight the relatively high turnover times in the coastal embayments in the wet season during previously identified low inflow years).

Consistency between Taylor River MLR Model and the FATHOM Model

Salinity predictions from the Taylor River MLR and FATHOM were compared along Transition Zone – northeast Florida Bay transect sites. Of the possible 384 monthly predictions that represented the historical period (32 years x 12 months), 25 observations had mean monthly salinity values between 25 and 35 psu at the Taylor river site (**Table 12**).

Table 12. Salinity Predictions of Taylor River MLR Model (at Taylor River site) and of FATHOM Model (at Little Madeira Bay and Eagle Key basin) during Periods of Salinity Stress (number of months of salinity between 25 psu and 35 psu at Taylor River site is 25 out of a possible 384 for period 1970–2000; when salinity values at the Taylor River site are near 30 psu, then the salinity values along the gradient in northeastern Florida Bay are near 40 psu; the low Spearman rank-order correlation probably reflects differential modeling errors per time point for both models).

	For TR values between 25-35		
	TR	**Little Madeira**	**Eagle**
N of cases	25	25	25
Minimum	24.5	25.8	30.8
Maximum	34.868	54.1	49.8
Range	10.368	28.3	19
Sum	711.085	975.5	989.1
Median	27.19	38.2	38.8
Mean	28.443	39.02	39.564
95% CI Upper	29.749	42.116	41.617
95% CI Lower	27.138	35.924	37.511
Std. Error	0.633	1.5	0.995
Standard Dev	3.163	7.501	4.973
Variance	10.003	56.263	24.727
C.V.	0.111	0.192	0.126
Skewness(G1	0.779	0.023	0.081
SE Skewness	0.464	0.464	0.464
Kurtosis(G2)	-0.818	-0.799	-0.556
SE Kurtosis	0.902	0.902	0.902
95%	34.023	50.05	47.1
	Spearman Correlation Matrix		
	TR	**Eagle**	**Little Madeira**
		0.18	0.199
		Number of Observations: 25	

These values were consistent with the mean and median values of near 30 psu for the Taylor River MLR model and with FATHOM output of approximately 40 psu for the downstream sites Little Madeira Bay and Eagle Key basin. The time series of the salinity over the 33-year historical period along the gradient illustrates that the two modeling approaches generally yielded consistent results, given position along the flow path (upstream to downstream) (**Figure 56**).

One exception occurred during the period from 1978 through 1981. The Taylor River MLR model's reconstruction shows fairly low salinities, with little relative difference between wet season and dry season, yet the FATHOM model shows fairly elevated salinities in Little Madeira Bay and Eagle Key during the same period. The Taylor River MLR model's salinity finding is consistent with the water level data at nearby Craighead Pond (CP) and with data from the P33-P35 gradient within Shark Slough.

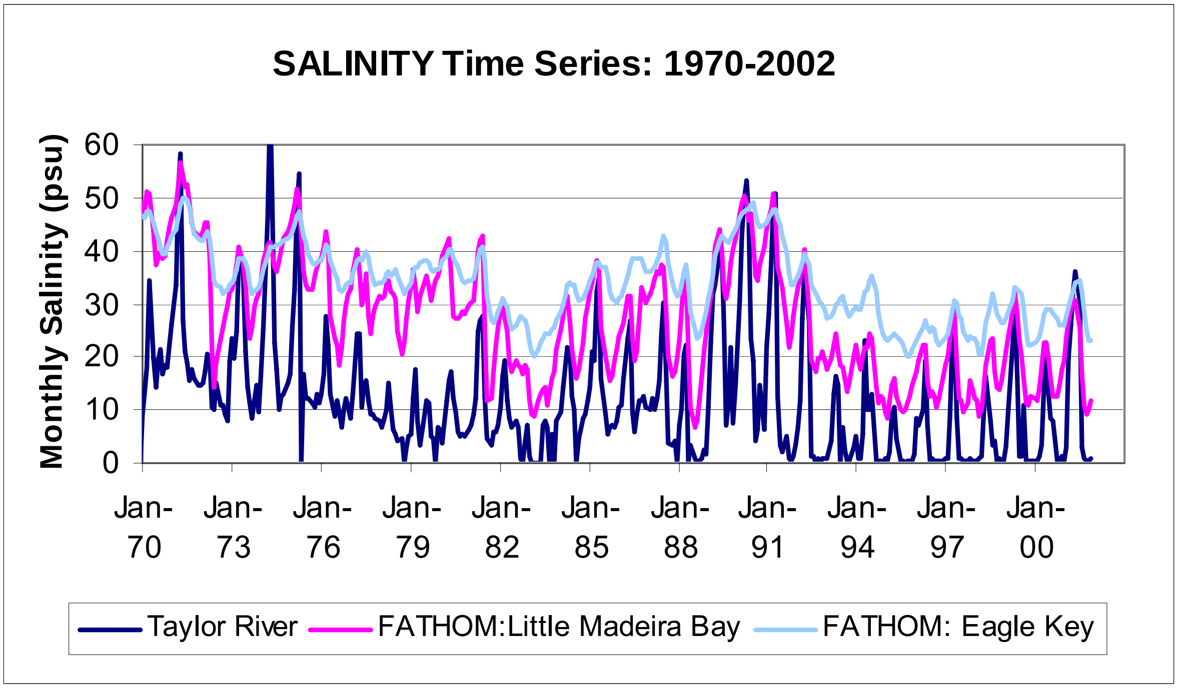


Figure 56. Consistency between Salinity Time Series by the MLR Model (dark blue for Taylor River site) and Salinity Time Series by the FATHOM Model (pink for Little Madeira Bay, light blue for Eagle Key basin) along the transition zone – bay transect (1970–2002).

The FATHOM model's predictions are consistent with flow data from the C-111 Canal and the Taylor Slough Bridge. Observational data are very limited, both spatially and temporally, during this time period, but the available data from various archived sources, as reported by Orlando et al. (1997) indicate that salinities (reported as combined average seasonal salinity), varied from 10 to near 40 psu in the coastal embayments (Little Madeira, Madeira Bay and Terrapin). The data could therefore support either or both model results. The reasons for the differences in salinity predictions between the two models and the difference with respect to the field data for this period are unknown. Further analyses will be presented, based on short-term (three-month) flow data and Taylor River salinity.

Structural Flows and Craighead Pond Stage During High Salinity Periods

Analyses were conducted to establish a connection between inflows to northeastern Florida Bay and periods when monthly average salinity at the Taylor River site exceeded 30 psu during consecutive years. Inflows to northeastern Florida Bay were calculated based on measures of freshwater flow at Taylor Slough Bridge (TSB) and at upstream water management structures S-18C and S-197, using the FATHOM historical reconstruction flow inputs (**Figure 57**). During and prior to periods when monthly average salinity at the Taylor River site exceeded 30 psu during consecutive years, the total average annual inflow to northeastern Florida Bay was less than 105,000 ac-ft per year for two consecutive years (**Figure 57**). The average annual flow directly into Little Madeira Bay in years when monthly average salinity at the Taylor River site exceeded 30 psu for multiple years in succession was less than 10,000 ac-ft per year (**Figure 58**). A more detailed analysis of flows indicated that monthly average salinities above 30 psu could occur even during years when total annual inflow was greater than 105,000 ac-ft per year. Such conditions occurred when 1) salinities at Taylor River at the beginning of the dry season were above 19 psu and 2) the preceding three-month total inflow into northeastern Florida Bay for any given month during the period January through March was less than 7,000 ac-ft (**Figure 59**). This finding illustrates the importance of considering the salinity impact of the timing of inflow in the transition zone.

TOTAL INFLOW INTO NE FLORIDA BAY (THOUSANDS ACRE-FEET)

	MONTH												
YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL TOTAL
1970	**2.4**	**1.0**	**0.3**	**0.0**	**2.9**	**12.2**	**17.0**	**0.8**	**3.6**	**8.7**	**1.2**	**0.0**	**50.0**
1971	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**9.3**	**0.2**	**0.3**	**5.6**	**2.9**	**0.9**	**1.3**	**20.5**
1972	0.0	0.0	0.0	4.4	16.2	79.3	29.1	11.3	8.5	7.4	5.4	0.1	161.8
1973	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**7.0**	**11.2**	**36.3**	**22.0**	**6.5**	**0.5**	**0.3**	**83.9**
1974	**0.0**	**0.0**	**0.0**	**2.3**	**0.0**	**7.5**	**12.3**	**7.6**	**4.2**	**5.1**	**0.0**	**0.0**	**39.0**
1975	**0.0**	**0.0**	**0.0**	**0.0**	**8.6**	**16.1**	**20.0**	**14.3**	**7.5**	**4.0**	**0.3**	**0.0**	**70.9**
1976	0.0	0.0	0.0	0.0	6.3	47.8	5.3	34.0	36.3	6.2	3.4	0.0	139.2
1977	0.0	0.0	0.0	0.0	16.7	26.3	1.8	4.9	58.7	7.5	0.8	1.5	118.1
1978	0.3	5.7	0.5	4.0	0.9	7.9	8.5	13.8	45.0	34.1	6.4	0.0	127.2
1979	0.0	0.0	0.0	21.2	14.0	3.2	7.0	1.2	21.5	6.6	0.2	5.1	80.0
1980	0.1	0.0	0.0	0.1	0.3	34.5	20.6	14.1	22.4	5.9	8.4	8.4	114.8
1981	0.0	9.3	0.1	0.0	0.0	0.0	0.3	81.4	60.8	29.2	3.4	0.0	184.5
1982	0.0	0.0	0.0	4.4	3.6	33.8	4.2	18.0	24.4	41.8	29.3	8.2	167.8
1983	18.4	42.1	32.1	26.9	3.9	29.1	11.5	32.4	59.1	4.3	31.1	1.2	292.1
1984	0.0	0.0	0.0	0.0	10.7	21.7	29.6	34.3	46.9	29.3	4.1	1.9	178.4
1985	2.9	1.2	1.0	0.6	0.2	2.2	60.3	28.9	52.0	51.7	24.9	5.7	231.5
1986	9.9	0.8	9.9	8.1	0.0	27.1	51.5	36.5	39.5	6.4	7.9	7.6	205.1
1987	8.2	0.9	5.9	0.2	9.3	6.5	9.5	19.4	31.4	54.8	45.3	19.1	210.4
1988	11.9	1.7	0.4	0.0	5.0	56.4	55.1	65.0	41.5	33.0	4.3	3.3	277.5
1989	**2.2**	**0.9**	**0.4**	**0.2**	**0.2**	**0.7**	**19.8**	**27.4**	**18.4**	**8.1**	**2.5**	**2.5**	**83.3**
1990	**1.9**	**0.8**	**0.4**	**0.2**	**6.6**	**7.0**	**6.0**	**32.2**	**17.9**	**22.5**	**5.3**	**2.4**	**102.9**
1991	2.5	1.9	0.9	0.1	18.3	28.3	12.8	20.6	49.7	42.7	8.5	2.9	189.2
1992	2.1	2.6	2.5	0.8	0.2	47.5	29.9	36.7	43.0	23.5	26.4	6.4	221.6
1993	27.0	7.8	8.5	5.0	7.9	32.6	30.0	31.3	43.5	62.0	24.4	6.8	286.8
1994	9.3	25.3	16.5	14.8	14.4	26.2	4.3	48.0	86.1	58.0	43.5	47.2	393.7
1995	42.3	23.4	13.1	10.8	21.0	48.4	47.0	54.1	43.2	33.8	24.6	12.2	374.0
1996	10.1	3.5	1.4	0.6	13.8	36.5	22.5	24.6	32.2	57.1	9.3	3.0	214.5
1997	1.8	1.0	0.7	0.5	3.5	79.9	39.6	55.1	62.6	20.6	2.6	44.0	312.0
1998	12.7	26.5	31.7	14.9	14.1	6.3	9.9	30.4	55.4	42.3	32.2	5.0	281.5
1999	11.1	3.7	0.7	0.2	0.5	21.0	22.2	41.0	60.7	78.3	36.5	27.0	302.8
2000	36.4	23.2	6.2	7.2	0.6	14.8	29.4	62.5	60.7	65.0	9.7	7.4	323.1
2001	0.2	0.0	0.0	0.2	1.2	9.3	28.3	60.0	64.5	70.0	51.6	26.7	312.1
2002	15.9	2.6	0.6	0.2	6.5	45.4	75.3	42.1	38.5	16.2	2.0	10.7	256.2

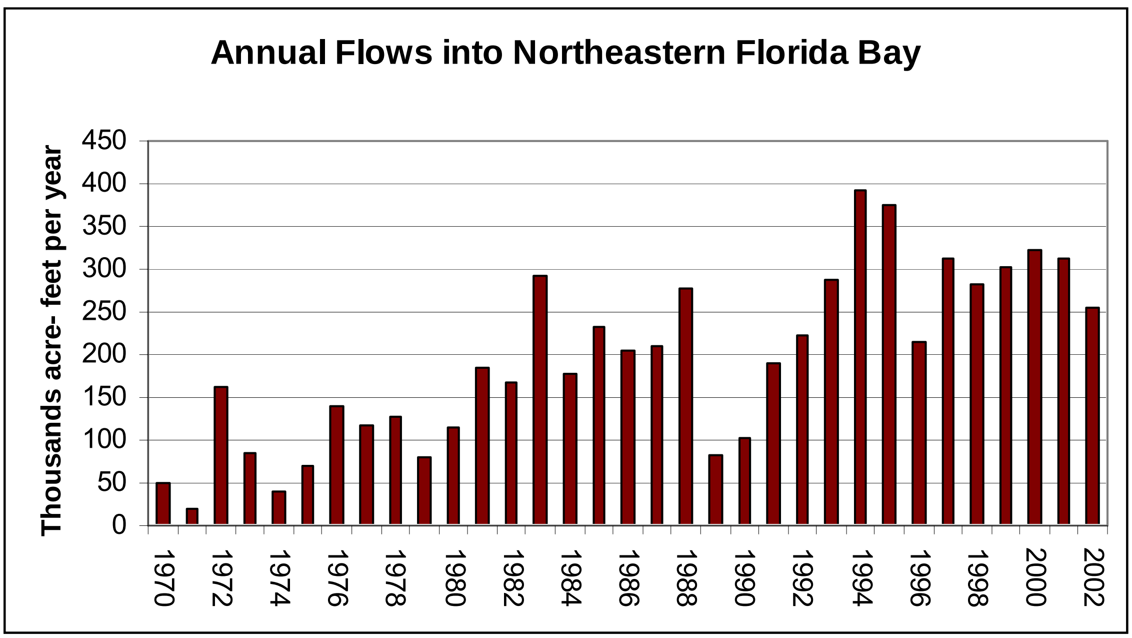


Figure 57. Inflows to Northeast Florida Bay. Data shown are FATHOM historical reconstruction flow inputs based on structure flows and water budget information (ECT, Inc. 2005). Years highlighted in orange (top panel) correspond to periods when the total annual flow was <105,000 ac-ft for Florida Bay for two consecutive years and correspond to periods previously identified as entailing sustained impacts to SAV resources in the transition zone. A year in which such an inflow level occurred for one year is highlighted in yellow. The majority of wet season inflows typically occurred June through November. Salinity conditions can exceed 30 psu at the Taylor River site in years when annual inflow is not low but inflows are delayed, such as 1991; the timing and duration of inflow may be important for some biota and should be considered in future restoration activities.

TOTAL INFLOW INTO LITTLE MADEIRA BAY (THOUSANDS ACRE-FEET)

	MONTH												
YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL TOTAL
1970	**0.2**	**0.1**	**0.0**	**0.0**	**0.3**	**1.0**	**1.4**	**0.1**	**0.3**	**0.8**	**0.1**	**0.0**	**4.3**
1971	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**0.0**	**0.0**	**0.5**	**0.3**	**0.1**	**0.1**	**2.0**
1972	0.0	0.0	0.0	0.4	1.6	7.4	2.4	1.0	0.7	0.6	0.5	0.0	14.7
1973	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.7**	**1.0**	**3.3**	**1.7**	**0.5**	**0.0**	**0.0**	**7.3**
1974	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**	**0.8**	**1.1**	**0.6**	**0.3**	**0.5**	**0.0**	**0.0**	**3.4**
1975	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**1.6**	**1.8**	**1.4**	**0.6**	**0.3**	**0.0**	**0.0**	**6.6**
1976	0.0	0.0	0.0	0.0	0.6	4.1	0.3	3.1	3.0	0.5	0.3	0.0	11.8
1977	0.0	0.0	0.0	0.0	1.6	2.1	0.1	0.4	5.0	0.6	0.0	0.1	9.9
1978	0.0	0.6	0.0	0.4	0.1	0.7	0.7	1.2	3.8	3.2	0.6	0.0	11.4
1979	0.0	0.0	0.0	2.1	1.2	0.2	0.6	0.1	2.0	0.5	0.0	0.5	7.2
1980	0.0	0.0	0.0	0.0	0.0	3.1	1.8	1.3	1.9	0.5	0.8	0.8	10.1
1981	0.0	0.9	0.0	0.0	0.0	0.0	0.0	7.1	5.2	2.3	0.2	0.0	15.8
1982	0.0	0.0	0.0	0.4	0.3	2.7	0.3	1.5	2.1	3.6	2.5	0.6	14.0
1983	1.6	3.9	3.2	2.7	0.4	2.7	1.0	3.1	5.6	0.3	3.0	0.1	27.6
1984	0.0	0.0	0.0	0.0	1.0	1.8	2.6	3.3	4.4	2.7	0.4	0.2	16.4
1985	0.3	0.1	0.1	0.1	0.0	0.2	5.6	2.6	4.9	5.0	2.4	0.6	21.9
1986	1.0	0.1	1.0	0.8	0.0	2.5	5.0	3.6	3.8	0.6	0.8	0.8	19.9
1987	0.8	0.1	0.6	0.0	0.9	0.6	0.9	1.7	3.0	5.1	4.5	1.9	20.1
1988	1.2	0.2	0.0	0.0	0.5	5.2	5.1	5.8	3.9	3.1	0.4	0.3	25.7
1989	**0.2**	**0.1**	**0.0**	**0.0**	**0.0**	**0.1**	**1.9**	**2.6**	**1.7**	**0.7**	**0.2**	**0.2**	**7.8**
1990	**0.2**	**0.1**	**0.0**	**0.0**	**0.7**	**0.6**	**0.4**	**3.1**	**1.6**	**2.1**	**0.5**	**0.2**	**9.6**
1991	0.2	0.2	0.1	0.0	1.8	2.6	1.1	1.9	4.7	3.8	0.7	0.3	17.3
1992	0.2	0.2	0.2	0.1	0.0	4.4	2.5	3.2	3.8	2.2	2.5	0.6	20.0
1993	2.6	0.7	0.7	0.4	0.7	3.0	2.5	2.6	3.7	5.5	2.1	0.5	25.0
1994	0.8	2.4	1.4	1.4	1.3	2.4	0.4	3.9	7.5	4.8	3.5	4.1	33.7
1995	3.7	2.0	1.2	1.1	1.9	4.3	3.9	4.7	3.6	2.6	2.0	0.9	31.9
1996	0.8	0.3	0.1	0.1	1.3	3.2	1.9	2.0	2.7	4.7	0.7	0.3	18.0
1997	0.2	0.1	0.1	0.1	0.3	6.5	3.3	4.6	5.1	1.8	0.2	3.5	25.7
1998	0.9	2.3	2.8	1.3	1.3	0.6	0.8	2.6	4.7	3.3	2.8	0.4	24.0
1999	0.9	0.3	0.1	0.0	0.0	1.9	2.0	3.5	5.1	6.0	2.8	2.1	24.7
2000	2.8	1.8	0.6	0.7	0.1	1.4	2.6	5.2	5.0	5.0	0.8	0.7	26.6
2001	0.0	0.0	0.0	0.0	0.1	0.9	2.6	5.1	5.4	5.4	3.9	2.2	25.6
2002	1.3	0.2	0.1	0.0	0.6	4.2	6.0	3.4	3.1	1.3	0.2	1.0	21.5

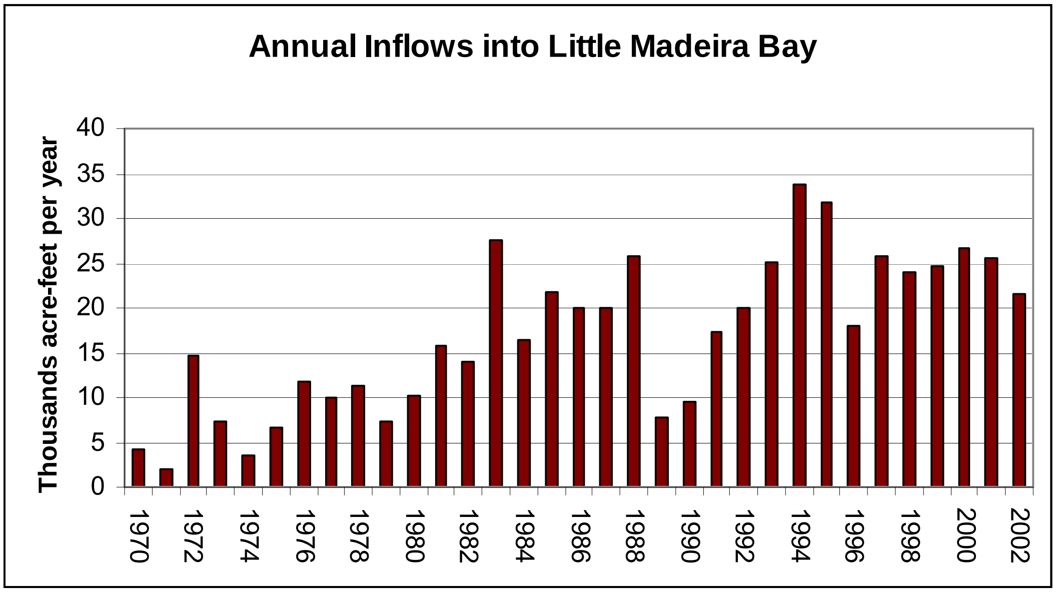


Figure 58. Inflows to Little Madeira Bay. Data shown are FATHOM historical reconstruction flow inputs based on structure flows and water budget information (ECT, Inc. 2005). Years highlighted in orange (top panel) correspond to periods in which the total annual flow was <10,000 ac-ft per year for Little Madeira Bay for two consecutive years and correspond to periods previously identified as entailing sustained impacts to SAV resources in the transition zone. Years in which such an inflow level occurred for one year are highlighted in yellow. The majority of wet season inflows typically occurred June through November. Salinity conditions can exceed 30 psu at the Taylor River site in years when annual inflow is not low but inflows are delayed, such as 1991; the timing and duration of inflow may be important for some biota and should be considered in more detail in future restoration activities.

PRIOR THREE MONTH SUM OF NORTHEASTERN FLORIDA BAY FLOWS (THOUSANDS ACRE-FEET)

YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1970	.	.	.	3.7	1.3	3.1	15.1	32.1	30.0	21.4	13.0	13.5
1971	9.9	1.2	0.0	0.0	0.0	0.0	9.3	9.5	9.7	6.0	8.8	9.4
1972	5.1	2.2	1.3	0.0	4.4	20.5	99.9	124.6	119.7	48.9	27.2	21.4
1973	13.0	5.6	0.2	0.1	0.0	0.0	7.0	18.2	54.5	69.5	64.9	29.0
1974	7.3	0.7	0.3	0.0	2.3	2.3	9.9	19.8	27.4	24.1	16.9	9.3
1975	5.1	0.0	0.0	0.0	0.0	8.6	24.7	44.7	50.4	41.8	25.9	11.9
1976	4.3	0.3	0.0	0.0	0.0	6.3	54.0	59.3	87.0	75.5	76.5	45.9
1977	9.6	3.4	0.0	0.0	0.0	16.7	43.0	44.7	32.9	65.3	71.1	67.0
1978	9.8	2.6	7.5	6.5	10.2	5.4	12.8	17.3	30.2	67.4	93.0	85.6
1979	40.5	6.4	0.0	0.0	21.2	35.2	38.4	24.2	11.4	29.7	29.3	28.3
1980	11.9	5.4	5.2	0.2	0.1	0.3	34.8	55.4	69.2	57.2	42.4	36.7
1981	22.7	16.8	17.6	9.4	9.4	0.1	0.0	0.3	81.7	142.5	171.4	93.4
1982	32.6	3.4	0.0	0.0	4.4	8.0	41.8	41.6	56.0	46.7	84.3	95.6
1983	79.4	55.9	68.7	92.6	101.1	62.9	59.9	44.5	73.0	103.1	95.9	94.5
1984	36.5	32.2	1.2	0.0	0.0	10.7	32.4	62.0	85.6	110.7	110.5	80.2
1985	35.3	8.9	6.0	5.1	2.8	1.8	3.0	62.7	91.3	141.1	132.5	128.6
1986	82.3	40.5	16.4	20.6	18.8	18.0	35.1	78.6	115.1	127.5	82.3	53.7
1987	21.9	23.6	16.7	15.0	7.0	15.4	15.9	25.3	35.4	60.3	105.5	131.5
1988	119.2	76.3	32.6	13.9	2.1	5.4	61.4	116.5	176.5	161.5	139.5	78.9
1989	40.7	9.8	6.4	3.5	1.4	0.7	1.1	20.8	48.0	65.6	53.9	29.0
1990	13.1	6.9	5.1	3.0	1.3	7.1	13.8	19.5	45.2	56.0	72.5	45.6
1991	30.2	10.2	6.8	5.3	2.9	19.3	46.7	59.5	61.7	83.1	112.9	100.8
1992	54.1	13.5	7.6	7.2	5.9	3.5	48.5	77.6	114.1	109.6	103.2	93.0
1993	56.3	59.8	41.1	43.3	21.3	21.4	45.5	70.5	93.9	104.8	136.7	129.9
1994	93.3	40.6	41.4	51.1	56.6	45.7	55.4	44.9	78.5	138.4	192.2	187.7
1995	148.8	133.1	112.9	78.8	47.3	44.9	80.2	116.4	149.5	144.3	131.1	101.6
1996	70.7	46.9	25.8	15.0	5.5	15.7	50.8	72.7	83.6	79.3	113.9	98.5
1997	69.4	14.1	5.8	3.5	2.3	4.8	83.9	123.0	174.6	157.4	138.3	85.8
1998	67.2	59.3	83.3	71.0	73.2	60.7	35.3	30.3	46.6	95.7	128.1	129.9
1999	79.5	48.2	19.7	15.5	4.6	1.4	21.7	43.7	84.2	123.9	180.0	175.5
2000	141.8	99.9	86.6	65.8	36.6	14.0	22.7	44.8	106.7	152.6	188.2	135.4
2001	82.1	17.3	7.6	0.2	0.2	1.4	10.7	38.8	97.6	152.8	194.5	186.1
2002	148.3	94.3	45.3	19.2	3.5	7.3	52.1	127.2	162.9	155.9	96.9	56.7
MAXIMUM	148.8	133.1	112.9	92.6	101.1	62.9	99.9	127.2	176.5	161.5	194.5	187.7
MINIMUM	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	9.7	6.0	8.8	9.3

Figure 59. Impact of Dry-Season Flows on Salinity Stress in the Transition Zone. Numbers indicate flows to Northeastern Florida Bay (thousands of ac-ft); red numbers indicate periods when salinity in transition zone is 19 psu or above 9polyhaline conditions); blue areas correspond to months when previous three-month total flows to northeast Florida Bay were 7,000 ac-ft or less; boxed areas show periods when both of these conditions occur simultaneously during the months January - March; these boxed times correspond to periods when monthly average salinity exceeded 30 psu in one year: 1985 and 2001 or during two or more consecutive years, (as indicated by yellow shading). Thus, a combination of polyhaline (or higher) salinities and low inflow at the onset of the dry season (January - March) leads to exceedance of the 30 psu salinity condition at the Taylor River site later in the year; the period 1978–1981, previously identified as having relatively low inflows to northeast Florida Bay, does not show polyhaline conditions until later in the dry season.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Conclusions

- Analysis of the 33-year historical reconstruction of salinity for the Taylor River site indicated that monthly average salinity exceeded 30 ppt during 12 of these years. In some cases, these high-salinity events occurred for two, three or four years in succession.
- During years when monthly average salinity exceeded 30 psu at the Taylor River site, and these conditions occurred in consecutive years, elevated salinities, including hypersaline conditions, occurred along the entire transition zone – Florida Bay transect. The magnitude and duration of high salinity events in the estuarine portion of the transect exceeded those in the wetland portion of the transect.

- The frequency and duration of these high-salinity events under reconstructed historical conditions could potentially have been reduced if current water management facilities and operational procedures had been in place throughout the reconstructed period
- Based on estimates from hydrologic models, an annual inflow of 105,000 ac-ft to northeastern Florida Bay is generally sufficient to avoid conditions that allow monthly average salinity at the Taylor River site to exceed 30 psu.
- Monthly average salinity exceeded 30 psu at the Taylor River site during periods of low water levels and low freshwater flow in the southeastern Everglades – typically during the dry season. More detailed analysis of these conditions indicated that if monthly average salinity at the Taylor River site was 19 psu or greater (polyhaline conditions) during any of the months from January through March, then (based on typical dry season rainfall patterns) salinity can be expected to exceed 30 psu during the subsequent three months.
- Modeling analyses suggest that maintenance of three-month (January through March) total inflow above 7,000 ac-ft should be sufficient to maintain monthly average salinity at the Taylor River site below 30 psu and thus protect resources in Taylor River and northeastern Florida Bay from experiencing impacts due to salinity stress later that year.
- Stage at the Craighead Pond site (CP) provides an additional local indicator that can be used to identify years in which critically low total annual inflow is anticipated. Periods when monthly average salinity at the Taylor River site exceeds 30 psu correspond to times when daily stage at CP falls below -1ft (relative to NGVD29) for any two consecutive years.
- Flows and stages sufficient to prevent monthly average salinity maxima at the Taylor River site below 30 psu should protect widgeon grass (*Ruppia*), SAV habitat, and associated resources along the transition zone gradient and also protect seagrass communities and associated biota in northeastern Florida Bay.

Recommendations for Future Work

The analyses presented in this report are based on best available information. The need for additional work is recognized. The following list summarizes limitations in the information presented and gives recommendations for future work:

- A monitoring program consistent with the MFL recommendations and objectives should be instituted. Current monitoring of hydrologic conditions, water quality and SAV in the southern Everglades and northeastern Florida Bay should be modified to improve information on the Everglades–Florida Bay salinity transition zone. Continued salinity monitoring should occur at the Taylor River site as well as at sites along the Little Madeira transect within Florida Bay. Creek flow monitoring (currently performed by USGS) should continue and possibly be expanded to quantify the ungauged flow. Efforts should be initiated to identify additional ecologic resources in coastal rivers, ponds and wetlands that may need to be monitored to provide better assessment of resource impacts.
- *Ruppia maritima* and other transition SAV, along with salinity, should be routinely monitored at several locations within the transition zone and within the coastal embayments of Florida Bay. Research on the response *Ruppia* to salinity levels and variability, including effects on seed production, seed bank viability, and reproductive success should be implemented. The dynamic model of Florida Bay SAV should be expanded to include *Ruppia*. These monitoring data should be used to develop a dynamic model of *Ruppia*. The habitat value of *Ruppia* and other SAV of the transition zone should be quantitatively assessed.
- Given the commercially valuable and ecologically sensitive resources in the central basins of Florida Bay (such as pink shrimp), further work should be pursued to quantify and predict inflow and its effects on salinity and biological resources. Ecologic resources and hypersalinity within these regions were not considered as a basis for the MFL criteria in this

report because with available models, a direct link to inflow could not be established. Linking flows and salinity was difficult because the total inflow is low and largely ungauged and the hydrodynamics of Florida Bay are complex. The models currently being developed as part of the CERP Florida Bay and Florida Keys Feasibility Study (FBFKFS) should be used in future evaluations.

- The spatial distribution and seasonal timing of inflow to northeastern Florida Bay should be included as elements to be investigated further in the FBFKFS and CERP projects. The final MFL criteria should be included as systemwide performance measures and should be considered in all projects and analyses that influence inflows into Florida Bay.
- Consideration should be given in the future to determination of the effects of potential consequences of Florida Bay MFL criteria on Shark Slough flows, the Whitewater Bay estuarine system and western Florida Bay. The Whitewater Bay estuarine system is indirectly coupled with Florida Bay via the Gulf of Mexico and is influenced by water management operations along the Tamiami Trail. Efforts to provide more flow to Taylor Slough and northeastern Florida Bay during dry periods may result in less flow to Shark Slough. Baseline information must be synthesized, monitoring necessities defined and modeling evaluations pursued to determine which resources can best be used to evaluate effects of freshwater flows to Whitewater Bay and western Florida Bay.
- Field tests should be conducted to verify the flow-salinity relationships derived in this report. Especially, controlled releases of water should be provided to Taylor River during the dry season to determine the relationships between the volume of water delivered and the resulting salinity conditions along the transect from the transition zone to Florida Bay.
- Relationships should be further investigated between salinity and gauged water levels and flows at various sites in Florida Bay and in the southern Everglades and C-111 basin. Future analyses should be based on improved hydrologic and hydrodynamic models currently being developed for the FBFKFS or other projects in the region.
- Any future Florida Bay MFL should be should be evaluated to ensure consistency with current Everglades MFL criteria. These criteria are based on stage (water level), so quantitative links need to be established relating Everglades stages to flows and salinity in Florida Bay.
- As new information and improved or new modeling tools become available and structural modifications of the water management system are made within the region, MFL criteria should be reviewed and revised as needed.